PROPERTY OF THE
PENNA. STATE LIBRARY

Bulletin No. 114

March 1935

COMMONWEALTH OF PENNSYLVANIA

DEPARTMENT OF INTERNAL AFFAIRS
Philip H. Dewey, Secretary

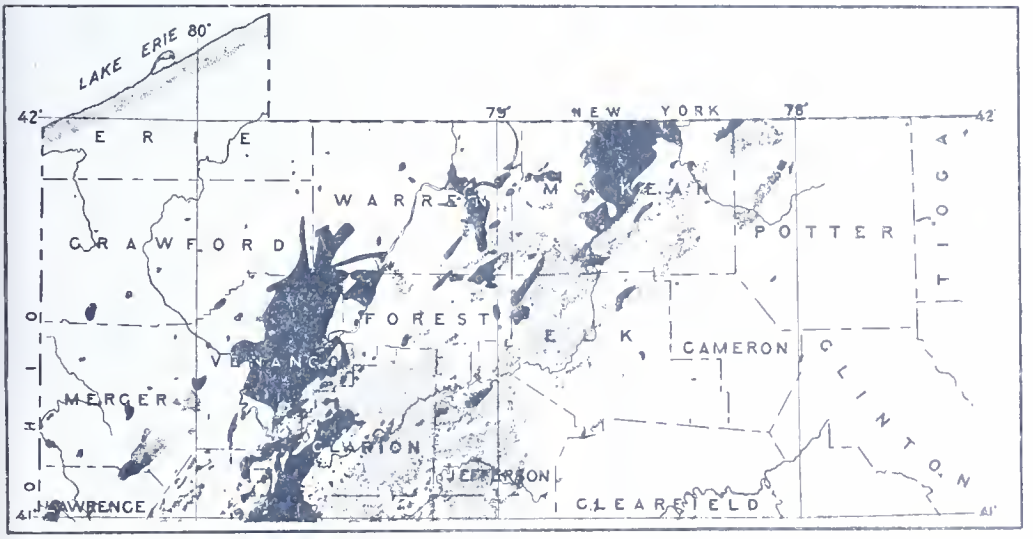
TOPOGRAPHIC AND GEOLOGIC SURVEY

George H. Ashley, State Geologist

SUBSURFACE STRATIGRAPHY OF NORTHWESTERN PENNSYLVANIA
and a
RESUME OF GAS AND OIL POSSIBILITIES OF DEEPER SANDS

By

Charles R. Fettke
Professor of Geology, Carnegie Institute of Technology, Pittsburgh



Oil and gas fields of northwestern Pennsylvania.

P38.12
2.4

CONTENTS

	Page
Introduction	1
Subsurface stratigraphy	2
Devonian-Mississippian boundary	8
Devonian system	10
Upper Devonian	10
Conewango group	10
Chemung group	11
Portage group	13
Genesee black shale	13
Tully limestone	13
Middle Devonian	14
Hamilton group	14
Onondaga limestone	14
Lower Devonian	14
Oriskany sandstone	14
Helderberg group	15
Silurian system	15
Cobleskill limestone	15
Salina group	15
Lockport dolomite	15
Clinton group	16
Medina group	16
Ordovician system	17
Queenston shale	17
Thickening of beds southeastward	17
Gas and oil possibilities of the deeper sands	18
Oriskany sandstone	18
Structure	20
Cementation and metamorphism	21
Gas and oil possibilities of the Oriskany	21
Salina group	22
Lockport group	22
Medina group	23

ILLUSTRATIONS

Figure 1.	Map showing extent and approximate depth of Oriskany sandstone in northwestern Pennsylvania	14
2.	Graphic representation of 13 deep well sections in western New York and northwestern Pennsylvania	14
3.	Outcrop sections at Niagara Falls, New York and Bellefonte, Pa., and 6 intervening well sections	19

PREFACE

Professor Fettke, as a cooperating member of the Geologic Survey, has for many years, as opportunity offered, been collecting samples of deep sands from western Pennsylvania and the adjoining States. His study of these is still far from complete, as his time for the past 10 years has been devoted to a most detailed study of the Bradford oil field.

This paper is offered as a report of progress covering a portion of the field in which there is at present a very live interest, in the hope that it will be both timely and helpful.

As in all other Survey publications of about this date, the stratigraphic nomenclature of the Upper Devonian is tentative.

March 1935.

Geo. H. Ashley

Digitized by the Internet Archive
in 2016 with funding from
This project is made possible by a grant from the Institute of Museum and Library Services as administered by the Pennsylvania Department of Education through the Office of Commonwealth Libraries

https://archive.org/details/subsurfacestrati00fett

INTRODUCTION

Prior to the recent discoveries of relatively large volumes of gas in the Oriskany sandstone in north central Pennsylvania, practically the entire production of gas and oil in the State was confined to Upper Devonian and higher strata. As the territory favorable for further testing of these higher formations has been becoming more and more limited, the deeper horisons, those below the Upper Devonian which have proven productive in the adjacent States of New York and Ohio, naturally have been attracting increasing attention. Drilling technique in recent years has been improved to such an extent that in Roane County, West Virginia it has been possible to reach a depth of 9104 feet with cable tools and in Jefferson County, Pennsylvania a well has attained a depth of 8227 feet, using only 795 feet of 6¼-inch casing.

On account of the expense involved in sinking these deep wells, it is important that as much geological data as possible be secured from each test so that further prospecting can be directed more intelligently. As part of its program of service to the mineral industries of the State, the Pennsylvania Topographic and Geologic Survey, in 1925, engaged the writer to make studies of drill cutting samples of such wells as they became available, so that in time a considerable fund of information would be secured on the subsurface stratigraphy of the gas and oil territory of the State and particularly the potential possibilities of the deeper horizons. This work has been in progress ever since to the extent that funds have been available for carrying it on. The present progress report contains part of the information obtained to date and outlines some of the conclusions that can be drawn therefrom. The work can by no means be considered completed, however. As drilling continues and more information becomes available, some of the opinions expressed may have to be changed materially.

When the work was first undertaken, it was not customary to take complete sets of drill cutting samples from all the strata penetrated by the drill. In the case of the earlier deep wells, therefore, the opportunity of obtaining much valuable geological information was lost. In recent years, however, practically all the major companies and many of the individual operators as well, have made it a practice to save such samples from all wildcat wells drilled to test the deeper horizons. Through the courtesy of the companies and individuals concerned, samples from a considerable number of these have been made available to the writer for examination.

In the laboratory, each sample is first spread out on a large watch glass and examined with a hand lens of 2½ X magnification. Then a small portion is placed on a 2-inch watch glass, and thoroughly washed with water to free the particles from adhering clay and other fine material. The particles are then examined under water with a pocket lens of 12 X magnification and tested with dilute hydrochloric acid for the presence of carbonates. It was found that the different types of rock particles can be more readily distinguished under water than in the dry state. All limestones are treated with dilute hydrochloric acid, and a qualitative test is made on them to determine the relative content of magnesium carbonate. The insoluble residues are examined under a binocular microscope.

Thus far cores have not been taken of the sands occurring at any of the deeper horizons. Only cuttings and occasional fragments have been available for examination. Cores of these sands would be highly desirable so that their porosities, permeabilities, degree of cementation and metamorphism, etc. could be determined for purposes of evaluating their potential possibilities as reservoir rocks for the occurrence of gas or oil in commercial quantities.

SUBSURFACE STRATIGRAPHY

Subsurface correlations have had to be based largely upon lithologic characteristics and stratigraphic sequence. Microscopic fossils which the drill cutting may contain are, as a rule, not identifiable because the fragments are too small. Although microscopic fossils are occasionally observed in the samples that have come to the writer's attention, they are not conspicuous.

The degree of refinement, therefore, that can be attained in subsurface correlations in the Appalachian plateau province is dependent in large measure upon the amount of information that is available in regard to the formations involved along their outcrops around the margins of the area with respect to such features as lithologic characteristics and thicknesses, lateral changes in these, stratigraphic sequence, fossil faunas, and proper correlations. As will be pointed out, there are still several outstanding problems involving correlations along outcrops of the strata represented in the subsurface sections of northwestern Pennsylvania that have not as yet been definitely solved.

Several wells in northwestern Pennsylvania, in Erie, Crawford, Warren, McKean, and Elk counties have penetrated the Queenston red shales of Upper Ordovician age. One well, drilled to a total depth of 4450 feet at Erie as early as 1888, is reported to have encountered the top of the Trenton limestone of the Middle Ordovician at 4280 feet[1]. Since 1925 complete sets of drill cutting samples have been taken from a considerable number of deep wells in western New York and northwestern Pennsylvania so that accurate sections of the strata penetrated can be constructed.

For the present report, the sections obtained from 13 wells have been selected to show the subsurface stratigraphy along a north and south belt extending from southern Erie County, New York, which lies well within the southern portion of the Medina gas belt of that State, to northern Elk County, Pennsylvania. The locations of these wells, numbered from 1 to 13, are shown on Figure 1. Well No. 10 is 70 miles south of No. 2. The sections are shown graphically in Figure 2 in as much detail as the scale permits. They have been lined up on the base of the Onondaga limestone, a horizon that is readily recognizable throughout the area under discussion.

A detailed description of Section 6 is given below to show the lithologic characteristics of the Upper and Middle Devonian beds in this area. It was obtained in the Ryder-Scott No. 1 well of J. Brooke Reed and associates, located near the head of Chipmunk Creek in Cattaraugus County, New York 1.2 miles north of the New York-Pennsylvania line, at an elevation of 1876 feet. It started in the Cattaraugus formation of the Upper Devonian and reached the bottom of the Oriskany sandstone. No fluids, either gas, oil, or water, were encountered in the Oriskany.

Record of J. Brooke Reed's Ryder - Scott No. 1 well

Thickness feet	Description of Strata	Depth in feet Top	Bottom
15	No samples	0	15
49	Fine-grained grayish-green sandstone, with some interbedded brick-red sandy shale in lower part	15	64
14	Greenish-gray sandy shale	64	78
16	Greenish-gray shale	78	94
5	Greenish-gray sandy shale	94	99

[1]. Charles S. Prosser: The Devonian and Mississippian Formations of Northwestern Ohio. Geological Survey of Ohio, Fourth Series, Bull. 15, pp. 412-422.

6	Medium to coarse-grained light greenish-gray sandstone, with some well rounded quartz grains up to 2 millimeters in diameter - Wolf Creek	99	105
	Bottom of Cattaraugus formation		105
16	Greenish-gray sandy shale	105	121
28	Greenish-gray shale, fossiliferous in lower part	121	149
25	Greenish-gray sandy shale	149	174
11	Greenish-gray shale, fossiliferous, with some interbedded purplish-gray sandy shale	174	185
35	Greenish-gray sandy shale	185	220
10	Greenish-gray shale	220	230
11	Dark greenish-gray sandy shale	230	241
5	Greenish-gray shalo	241	246
6	Greenish-gray sandy shale	246	252
12	Dark greenish-gray shale, with some interbedded grayish-green sandy shale	252	264
6	Greenish-gray sandy shale	264	270
12	Greenish-gray sandy shale, with some interbedded purplish-gray sandy shale	270	282
23	Greenish-gray sandy shale, fossiliferous	282	305
6	Very fine-grained dark greenish-gray sandstone with some interbedded dark greenish-gray shale	305	311
6	Dark greenish-gray shale, fossiliferous, with some interbedded dark purplish-gray sandy shale	311	317
16	Greenish-gray sandy shale, fossiliferous	317	333
16	Grayish-purple sandy shale	333	349
5	Greenish-gray sandy shale, fossiliferous, with some interbedded grayish-purple sandy shale	349	354
5	Dark greenish-gray sandy shale	354	359
16	Greenish-gray shale	359	375
10	Very fine-grained light greenish-gray sandstone very fossiliferous	375	385
23	Grayish-purple sandy shale and shale, with some interbedded greenish-gray shale	385	408
5	Greenish-gray sandy shale	408	413
55	Grayish-purple sandy shale, with some interbedded greenish-gray shale	413	468
18	Very fine-grained light greenish-gray fossiliferous sandstone with some interbedded greenish-gray and purplish-gray shale - Hinsdale	468	486
	Bottom of Chadakoin beds		486
48	Gresnish-gray shale	486	534
6	Greenish-gray sandy shale	534	540
6	Dark greenish-gray shale	540	546
6	Greenish-gray sandy shale, fossiliferous	546	552
11	Greenish-gray shale, with some interbedded greenish-gray sandy shale	552	563
20	Dark greenish-gray shale, with some interbedded greenish-gray sandy shale	563	583
5	Very fine-grained greenish-gray sandstone, fossiliferous	583	588
15	Dark greenish-gray shale	588	603
2	Very fine-grained greenish-gray sandstone, fossiliferous	603	605
23	Dark greenish-gray shale, with some interbedded dark greenish-gray ssndy shale, fossiliferous	605	628
3	Fine-grained reddish-brown ferruginous sandstone, slightly calcareous	628	631
20	Interbedded dark greenish-gray shale and greenish-gray sandy shale	631	651
10	Greenish-gray shale	651	661
10	Dark greenish-gray sandy shale, fossiliferous	661	671
12	Dark greenish-gray shale, with some interbedded greenish-gray sandy shale	671	683

12	Greenish-gray sandy shale, very fossiliferous	683	695
8	Greenish-gray shale	695	703
8	Greenish-gray sandy shale, very fossiliferous	703	711
4	Very fine-grained light greenish-gray sandstone, very fossiliferous	711	715
18	Dark greenish-gray shale	715	733
18	Very fine-grained light greenish-gray sandstone, somewhat calcareous in lower part, with some interbedded greenish-gray shale	733	751
15	Greenish-gray to dark gray shale	751	766
5	Dark greenish-gray sandy shale	766	771
12	Dark gray shale	771	783
10	Medium to coarse-grained white sandstone, with quartz grains up to 2 millimeters in diameter. Somewhat calcareous in upper part; salt water encountered in this sand - Bradford First sand - Cuba	783	793
	Bottom of Girard beds		793
26	Greenish-gray sandy shale	793	819
17	Greenish-gray shale	819	836
10	Greenish-gray sandy shale	836	846
9	Very fine-grained pale grayish-brown sandstone, fossiliferous, with some interbedded greenish-gray shale	846	855
8	Fine-grained light gray sandstone, fossiliferous, with some interbedded greenish-gray shale - Sugar Run	855	863
8	Greenish-gray shale	863	871
8	Fine-grained light greenish-gray sandstone, with some interbedded greenish-gray shale	871	879
48	Greenish-gray shale, with some interbedded greenish-gray sandy shale	879	927
7	Fine-grained light gray sandstone, slightly calcareous	927	934
12	Gray shale, with some interbedded fine-grained light gray sandstone, slightly calcareous	934	946
51	Greenish-gray shale	946	997
	Top of Chipmunk sand	997	
4	Fine-grained light grayish-brown sandstone	997	1001
5	Dark greenish-gray shale	1001	1006
38	Fine-grained light grayish-brown sandstone, with a little interbedded gray shale	1006	1044
	Bottom of Chipmunk sand		1044
81	Greenish-gray shale, in part sandy	1044	1125
	Top of Bradford Second sand	1125	
4	Fine-grained chocolate-brown sandstone	1125	1129
7	Greenish-gray shale	1129	1136
6	Greenish-gray sandy shale, with a little interbedded fine-grained light greenish-gray sandstone	1136	1142
14	Very fine-grained chocolate-brown sandstone, slightly calcareous, with some interbedded greenish-gray shale	1142	1156
	Bottom of Bradford Second sand		1156
	Bottom of Northeast beds		1156
35	Greenish-gray shale, with some interbedded very fossiliferous greenish-gray sandy shale in lower part	1156	1191
9	Very fine-grained grayish-brown sandstone, somewhat calcareous - Harrisburg Run	1191	1200
33	Greenish-gray shale	1200	1233
31	Interbedded greenish-gray sandy shale and shale, fossiliferous	1233	1264
41	Greenish-gray shale	1264	1305

8	Greenish-gray sandy shale	1305	1313
70	Greenish-gray shale	1313	1383
20	Greenish-gray sandy shale, fossiliferous	1383	1403
16	Greenish-gray shale	1403	1419
91	Interbedded very fine-grained grayish-brown sandstone and greenish-gray shale - Bradford Third sand	1419	1510
105	Greenish-gray shale, with a little interbedded very fine-grained grayish-brown and light greenish sandstone	1510	1615
	Bottom of Westfield beds		1615
73	Greenish-gray shale, with some interbedded greenish-gray sandy shale	1615	1688
8	Very fine-grained brown sandstone, slightly calcareous, with much interbedded greenish-gray shale, - Kane	1688	1696
21	Gray sandy shale	1696	1717
38	Gray shale	1717	1755
36	Gray to dark gray sandy shale	1755	1791
8	Dark brownish-gray sandy shale	1791	1799
42	Gray to dark gray shale	1799	1841
27	Greenish-gray shale, with some interbedded greenish-gray sandy shale, fossiliferous	1841	1868
41	Gray shale	1868	1909
9	Gray sandy shale	1909	1918
8	Gray shale	1918	1926
12	Very fine-grained light greenish-gray sandstone with a little interbedded gray shale - Humphrey	1926	1938
25	Gray to very dark gray shale	1938	1963
15	Greenish to dark greenish-gray sandy shale	1963	1978
	Bottom of Gowanda beds		1978
25	Gray shale, with a little interbedded very dark gray shale	1978	2003
9	Very dark gray shale	2003	2012
19	Gray shale	2012	2031
17	Very dark gray sandy shale	2031	2048
17	Gray shale	2048	2065
9	Gray sandy shale	2065	2074
9	Gray shale, with a little interbedded very fine-grained light gray sandstone	2074	2083
8	Gray sandy shale	2083	2091
7	Gray shale, with some interbedded grayish-black shale	2091	2098
27	Gray sandy shale, with some interbedded gray shale	2098	2125
15	Gray shale, with some interbedded dark gray shale	2125	2140
20	Gray to very dark gray sandy shale	2140	2160
8	Gray shale	2160	2168
20	Grayish-black shale, with some interbedded gray sandy shale	2168	2188
	Bottom of Dunkirk black shale and Chemung group		2188
6	Gray shale, with a little interbedded grayish black shale	2188	2194
9	Dark gray sandy shale, with some interbedded gray shale	2194	2203
43	Greenish-gray sandy shale, with a little interbedded very dark gray shale	2203	2246
9	Greenish-gray sandy shale, with some interbedded grayish-black shale	2246	2255
32	Greenish-gray sandy shale	2255	2287
51	Gray shale, with a little interbedded gray to dark gray sandy shale	2287	2338
11	Very dark gray, almost black, shale	2338	2349
5	Very fine-grained light gray sandstone, with considerable interbedded grayish-black shale	2349	2354

9	Dark gray sandy shale, with a little very fine-grained gray sandstone, somewhat calcareous	2354	2363
14	Dark gray to very dark gray, almost black shale, with some interbedded gray sandy shale	2363	2377
7	Black shale, with a little interbedded very fine-grained light greenish-gray sandstone, slightly calcareous	2377	2384
9	Light greenish-gray sandy shale	2384	2393
	Bottom of Wiscoy beds		2393
5	Very fine-grained greenish-gray sandstone, slightly calcareous	2393	2398
29	Greenish-gray sandy shale	2398	2427
7	Very fine-grained greenish-gray sandstone, slightly calcareous	2427	2434
4	Gray shale	2434	2438
15	Greenish-gray sandy shale, with some interbedded gray shale	2438	2453
5	Dark greenish-gray shale	2453	2458
10	Gray shale	2458	2468
7	Very fine-grained greenish-gray sandstone, slightly calcareous, with some interbedded dark gray shale	2468	2475
8	Gray shale	2475	2483
9	Greenish-gray sandy shale	2483	2492
9	Very fine-grained light greenish-gray sandstone	2492	2501
18	Greenish-gray sandy shale	2501	2519
9	Gray shale	2519	2528
24	Very fine-grained light greenish-gray sandstone, with some interbedded grayish-black shale	2528	2552
	Bottom of Nunda beds		2552
7	Greenish-gray sandy shale	2552	2559
28	Gray to dark gray sandy shale	2559	2587
8	Gray shale	2587	2595
55	Greenish-gray sandy shale	2595	2650
80	Dark gray shale	2650	2730
8	Greenish-gray sandy shale	2730	2738
8	Dark gray shale	2738	2746
17	Greenish-gray sandy shale; small show of gas	2746	2763
11	Dark gray shale, with a little interbedded grayish-black shale	2763	2774
6	Greenish-gray sandy shale	2774	2780
15	Dark gray shale, with some interbedded dark greenish-gray sandy shale	2780	2795
	Bottom of Gardeau beds		2795
7	Very fine-grained greenish-gray sandstone - Grimes	2795	2802
10	Gray shale	2802	2812
23	Greenish to dark greenish-gray shale	2812	2835
50	Gray shale	2835	2885
9	Gray shale, with some interbedded grayish-black shale	2885	2894
45	Gray to very dark gray shale	2894	2939
13	Very fine-grained brownish-gray sandstone, slightly calcareous	2939	2952
11	Dark gray shale	2952	2963
5	Very fine-grained gray sandstone	2963	2968
10	Very fine-grained brownish-gray sandstone	2968	2978
56	Dark gray shale, with a little interbedded very fine-grained gray sandstone	2978	3034
14	Dark gray shale, with some interbedded grayish-black shale	3034	3048
30	Dark gray shale, with a little interbedded very fine-grained gray sandstone	3048	3078
32	Grayish-black shale	3078	3110
63	Gray to dark gray shale	3110	3173

20	Grayish-black shale	3173	3193
11	Gray to dark gray shale	3193	3204
5	Grayish-black shale	3204	3209
20	Dark gray shale	3209	3229
	Bottom of Hatch beds		3229
40	Grayish-black shale, with a little interbedded dark gray shale	3229	3269
34	Gray to dark gray shale	3269	3303
18	Grayish-black shale, with some interbedded gray shale	3303	3321
	Bottom of Rhinestreet black shale		3321
74	Dark gray shale	3321	3395
121	Dark gray shale, slightly calcareous	3395	3516
26	Very dark gray shale, slightly calcareous	3516	3542
	Bottom of Cashaqua shale		3542
5	Grayish-black shale	3542	3547
10	Very dark gray shale	3547	3557
101	Grayish-black shale	3557	3658
	Bottom of Middlesex black shale		3658
29	Very dark gray shale, slightly calcareous	3658	3687
17	Very dark gray, almost black, shale, somewhat calcareous	3687	3704
	Bottom of West River shale and Portage group		3704
34	Black shale, calcareous	3704	3738
12	Black shale, slightly calcareous	3738	3750
13	Grayish-black shale	3750	3763
18	Black shale, slightly calcareous	3763	3781
	Bottom of Genesee black shale		3781
4	Very fine, dense, grayish-brown limestone - Tully	3781	3785
	Top of Hamilton group	3785	
36	Very dark gray shale, somewhat calcareous	3785	3821
18	Dark to very dark gray shale, slightly calcareous	3821	3839
2	Very fine, dense light brownish-gray limestone, very fossiliferous - Tichenor	3839	3841
51	Very dark gray shale, somewhat calcareous	3841	3892
24	Very dark gray shale, calcareous	3892	3916
3	Very fine, dense grayish-brown limestone	3916	3919
23	Dark to very dark gray shale, calcareous	3919	3942
20	Dark to very dark gray shale, somewhat calcareous	3942	3962
6	Very dark gray shale, calcareous	3962	3968
27	Grayish-black shale, somewhat calcareous	3968	3995
6	Grayish-black shale, calcareous	3995	4001
41	Very dark gray shale, somewhat calcareous	4001	4042
39	Grayish-black shale, somewhat calcareous	4042	4081
2	Very fine, dense, grayish-brown limestone - Centerfield	4081	4083
60	Grayish-black shale, somewhat calcareous	4083	4143
19	Dark gray shale, somewhat calcareous	4143	4162
15	Very dark gray shale, calcareous	4162	4177
19	Dark to very dark gray shale, somewhat calcareous	4177	4196
35	Black shale, calcareous	4196	4231
22	Black shale, somewhat calcareous	4231	4253
1	Very fine, dense, grayish-brown limestone	4253	4254
15	Black shale	4254	4269
6	Black shale, calcareous	4269	4275
	Top of Onondaga limestone	4275	
8	Very fine, crystalline, dark grayish-brown limestone	4275	4283
57	Very fine, dense, very dark grayish-brown limestone - gas pocket at 4304-4306	4283	4340
13	Very fine, crystalline, light brownish-gray oherty limestone	4340	4353
	Top of Oriskany sandstone	4353	
7	Medium-grained light gray sandstone - calcareous	4353	4360
3	Medium-grained light gray sandstone, slightly		

	calcareous	4360	4363
7	Medium-grained, light gray sandstone, somewhat calcareous	4363	4370
	Total depth		4370

The Ryder-Scott deep well is located on the northern margin of the Bradford oil pool, the type locality for the Bradford Third sand, the main producing horizon of the Bradford field, as well as for the Bradford First and Second sands. The Bradford First sand in the vicinity of the well contains so much salt water that this has to be cased off in drilling through it. The Chipmunk oil pool, the type locality for the Chipmunk sand, is along Chipmunk Creek about 2 miles to the northwest. Oil production is obtained from both the Chipmunk and Bradford Second sands at the head of Nichol Run about 1 mile west of the well. The section has been selected because it shows the relations of these various sands to one another and their stratigraphic positions in the Upper Devonian section.

The thicknesses of the major subdivisions of the Devonian and Silurian systems in the 13 deep well sections shown in Figure 2 are summarized in Table 1.

DEVONIAN-MISSISSIPPIAN BOUNDARY

The position of the Devonian-Mississippian boundary in northwestern Pennsylvania has long been a mooted question. Butts and Clarke in 1903 placed the boundary at the base of the Cattaraugus formation[2]. The New York State Geological Survey still draws the line between the Mississippian and Devonian systems at this horizon[3]. Glenn, on the other hand, thought that the line should be drawn at the top of the Cattaraugus[4]. A little later Girty, on the basis of an analysis of the fossil faunas present in the beds involved, came to the conclusion that the break comes at the base of the Berea-Corry horizon[5].

---

[2] Charles Butts: Fossil Faunas of the Olean Quadrangle. New York State Museum Bull. 69, 1903, p. 991.

John M. Clarke: Construction of the Olean Rock Section. New York State Museum Bull. 69, 1903, p. 999.

[3] Winifred Goldring: Handbook of Paleontology, Part 2: The formations. New York State Museum Handbook 10, 1931, p. 424.

[4] L. C. Glenn: Devonic and Carbonic Formations of Southwestern New York. New York State Museum Bull. 69, 1903, pp. 985-986.

[5] George H. Girty: Comparison of Section of Upper Paleozoic Rocks in Ohio and Northwestern Pennsylvania. Science, N.S., vol. XIX, 1904, pp. 24-25.

The Relations of Some Carboniferous Faunas. Washington Acad. of Sciences, Proc., vol. VII, 1905, pp. 6-7.

Geologic Age of the Bedford Shale of Ohio. Annals New York Acad. Sci., vol. XII, 1912, p. 307.

Table 1.

Thicknesses in feet of Major Subdivisions of Devonian and Silurian Systems.

Section Number	1	2	3	4	5	6	7	8	9	10	11	12	13
MISSISSIPPIAN SYSTEM													
Cussewago-Knapp										200			
DEVONIAN SYSTEM													
Conowango group													
Oswayo										170			
Cattaraugus						105+			263+	327	56+		
Chemung group	2077	783+			1980+	2083		2400	4251	2308	2497	2233	800+
Portage group	883	686			1638	1616		1817		1768	1815	1654	1440
Genesee	abst.	abst.	1651+	3960	125	77	4190	125	140	99	199	163	100
Tully	abst.	abst.			5	4		16	4	6	48	32	64
Hamilton group	420	341			427	490		458	465	440	532	465	452
Onondaga	154	160	225	133	101	78	70	48	59	82	27	86	95
Oriskany	abst.	abst.	abst.	abst.	15	17	20	abst.	abst.	abst.	5	5	21
Helderberg group	abst.	abst.	abst.	abst.	5+		60	57	60	20	66	abst.	abst.
SILURIAN SYSTEM													
Cobleskill	9	6	548	744			20	25	27	28	5	18	23
Salina group	667	490					860	317+		1132	300+	824	324
Lockport	274	195	226	248			300			320		296	
Clinton group	140	121	119	126			175			176		248	
Medina group	89+	108	91	107			140			166		134	
ORDOVICIAN SYSTEM													
Queenston		18+	21+	129+			120+			688+		92+	

Ver Wiebe, after reviewing the problem in the field, agreed with Girty that the boundary should be drawn at the base of the Berea[6]. Chadwick in 1925 pointed out the probable equivalence of the Cussewago and Knapp beds and concluded that the Devonian-Mississippian unconformity occurs at their top[7]. Caster, who has made the most recent careful field studies in the area involved, on the other hand, largely on the evidence of fossils, concludes that the boundary between the Devonian and Mississippian systems occurs at the base of the Cussewago-Knapp beds[8].

In Table 1 the Cussewago-Knapp beds have been tentatively listed under the Mississippian system. Butts has shown that these beds are older than the strata included in the so-called Pocono group in southwestern Pennsylvania, which are generally conceded to be of Mississippian age[9].

DEVONIAN SYSTEM

The Devonian system of northwestern Pennsylvania has been classified as follows:

Upper Devonian	(Conewango group (Oswayo formation (Cattaraugus formation (Chemung group (Portage group (Genesee black shale (Tully limestone
Middle Devonian	(Hamilton group (Onondaga limestone
Lower Devonian	(Oriskany sandstone (Helderberg group

Upper Devonian

Conewango Group

The Cattaraugus formation constitutes the northwestern representative of the series of Devonian red beds to which the name Catskill is usually applied. Lithologically, the Cattaraugus formation, in many respects, resembles

---

6. Walter A. Ver Wiebe: The Berea Formation of Ohio and Pennsylvania. Am. Jour. Sci., vol. XLII, July, 1916, pp. 43-58.
Correlation of the Mississippian of Ohio and Pennsylvania. Am. Jour. Sci., vol. XLIII, April, 1917, pp. 301-313.
Correlation of the Devonian Shales of Ohio and Pennsylvania. Am. Jour. Sci., vol. XLIV, 1917, pp. 33-47.

7. George H. Chadwick: Chagrin Formation of Ohio. Geol. Soc. America, Bull., vol. 36, 1925, p. 463.

8. Kenneth E. Caster: Stratigraphic Relationships in Northwestern Pennsylvania (abstract). Geol. Soc. America, Bull., vol. 44, 1933, pp. 202-203.
The Stratigraphy and Paleontology of Northwestern Pennsylvania, Part I: Stratigraphy. American Paleontology, Bull., vol. 21, no. 71, 1934, pp. 104-106.

9. Charles Butts: Pre-Pennsylvanian Stratigraphy. Report of the Topographic and Geologic Survey Commission of Pennsylvania, 1906-1908, 1908, p. 197.

the Catskill of southeastern New York and eastern and central Pennsylvania. Traced eastward by outcrops and well records, the two are found to merge into one another. This does not imply that they are contemporaneous, however. The Catskill type of sedimentation started much earlier in southeastern New York and eastern Pennsylvania than in the western parts of these States and it is now known that even the uppermost of the Catskill strata in the Catskill region are considerably older than the Cattaraugus beds of western New York and adjacent portions of Pennsylvania, as was pointed out in 1887 by Williams when he stated there is reason to believe that in Sullivan County, New York the deposition of red beds started as early as Hamilton time[10], an observation that has recently been verified by Chadwick and Cooper in the Catskill area of New York and by Willard in northeastern Pennsylvania[11].

In McKean, northern Elk, and western Potter counties, Pennsylvania the bottom of the Cattaraugus formation, the base of the Catskill type of red beds, appears to represent a nearly contemporaneous plane of deposition and hence can be used for correlation purposes. To the east and southeast of this area, the red beds descend progressively lower and lower in the geologic column. To the west they become less and less conspicuous and finally disappear entirely. In this area Butts has, therefore, grouped the Oswayo and Cattaraugus together under the name Conewango[12].

The Cattaraugus formation represents approximately the same stratigraphic interval as that occupied by the Venango Oil Sand group of the Venango district as originally defined by Carll[13].

Chemung Group

D. Dana Luther, in 1902, on the evidence of fossils, placed the bottom of the Chemung at the base of the Long Beards Riffs sandstone which crops out along the Genesee River, half a mile south of Fillmore in northern Allegany County, New York[14]. Chadwick has shown that the base of the Dunkirk black shale of the Lake Erie section corresponds in stratigraphic position to the base of the Long Beards Riffs sandstone[15]. In 1924, Chadwick agreed with Luther that the base of that sandstone represents the bottom of the Chemung group. More recent and detailed studies by Chadwick in central and western New York have led him to the conclusion that the base of the Chemung group occurs at the base of the Grimes sandstone, hitherto considered to lie at about the middle of the Portage group[16].

---

[10] Henry S. Williams: On the Fossil Faunas of the Upper Devonian; the Genesee Section, New York. U. S. Geol. Survey Bull. 41, 1887, p. 27.

[11] George H. Chadwick: Catskill Formation (abstract). Geol. Soc. America, Bull., vol. 42, 1931, pp. 242-243.
Hamilton Red Beds in Eastern New York, Science, N.S., vol. 77, 1933, pp. 86-87.
G. Arthur Cooper: Stratigraphy of the Hamilton Group of Eastern New York (abstract). Geol. Soc. America, Bull., vol. 44, 1933, pp. 200-201.
Bradford Willard: "Catskill" Sedimentation in Pennsylvania. Geol. Soc. America, Bull., vol. 44, 1933, pp. 495-516.

[12] Charles Butts: Description of the Warren Quadrangle. U. S. Geol. Survey, Geol. Atlas, Folio No. 172, 1910, p.4.

[13] John F. Carll: The Geology of the Oil Regions. Pennsylvania Second Geol. Survey, Report I 3, 1880, p. 130.

[14] D. Dana Luther: Stratigraphy of Portage Formation between the Genesee Valley and Lake Erie. New York State Museum Bull. 69, 1903, p. 1009.

[15] George H. Chadwick: The Stratigraphy of the Chemung Group in Western New York. New York State Museum Bull. 251, 1924, pp. 149-150.

[16] George H. Chadwick: Great Catskill Delta: and Revision of Later Devonic Succession, III, Revised Correlations. Pan-American Geologist, vol. LX, 1933, p. 353.

It has been customary in western Pennsylvania to include all the strata from the top of the Portage group to the base of the Cattaraugus formation or its equivalent to the west, the Venango, in the Chemung group. Attention must be called to the fact that the upper beds thus included are younger than the Chemung beds of the type locality around the sides of Narrow Hill, at Chemung Narrows, west of Chemung, in south-central New York. This necessarily follows since, as has been pointed out, the Catskill type of sedimentation, of which the Cattaraugus represents only the last stage, began progressively earlier as one goes eastward and southeastward. Chadwick now thinks that the base of the Dunkirk black shale represents the top of the Chemung group instead of the bottom[17]. This would place all the strata that have been included in that group in northwestern Pennsylvania, above the true Chemung. While the writer is not inclined to go as far as Chadwick, he realizes that after a thorough restudy of the Upper Devonian stratigraphy of New York and Pennsylvania has been completed, it will be found necessary to make some revisions in the classification now in use. The older grouping is the one shown in Figure 2.

In northwestern Pennsylvania, the productive oil and gas sands developed to date have been confined almost entirely to the Upper Devonian. For the Bradford district, the intervals between important horizons and the top of the Bradford Third sand are shown in Table 2.

Table 2.

Intervals between important horizons and the top of the Bradford Third sand in the Bradford district

	Average Interval feet	Minimum Interval feet	Maximum Interval feet
Base of Olean	1895	1791	1979
Top of Cattaraugus red beds . . .	1575	1507	1708
Bottom of Cattaraugus red beds . .	1255	1183	1282
Top of sands:			
Bradford First	610	560	658
Sugar Run	525	483	559
Chipmunk	440	384	484
Bradford Second	325	284	390
Harrisburg Run (new name) . .	230	176	271
Bradford Third	0	0	0
Lewis Run (4th)	100	64	168
Kane (5th)	240	184	309
Haskell (6th)	450	408	511

The Bradford First sand is represented by the Cuba sandstone on the outcrop. The Glade sand of the Warren district occupies approximately the same horizon. The Sugar Run sand corresponds closely in stratigraphic position to the Clarendon, while the Chipmunk corresponds to the Gartland and Cherry Grove. The Bradford Second sand is represented to the south and southwest by the Sheffield and Cooper sands. The Richburg sand of Allegany County, New York corresponds very closely in stratigraphic position to the Bradford Third, as does the Crandall Hill sand of western Potter County, Pennsylvania. The Haskell sand is usually called the Elk in southeastern McKean County.

In core samples of the Bradford Third sand, collected by Messrs. Jerry B. Newby and Paul D. Torrey in 1926 in the Bradford district, Charles Butts identified the following fossils[18]:

17. George H. Chadwick. Idem, p. 355.

18. Charles Butts: Written communication, April 28 and Nov. 3, 1926.

Productella lachrymosa ? Camarotoechia contracta. Edmondia obliqua ?
Productella hirsuta ? Spirifer mesacostalis.

In a collection of fossils obtained by the writer from cores of the cap-rock above the Bradford Third sand in the same district, the following forms were present[19]:

Schuchertella chemungensis. Leiorhynchus mesacostale.
Productella, probably Productella lachrymosa. Cryptonella ?
Dalmanella ?, probably Dalmanella tioga. Spirifer mesacostalis.
Camarotoechia contracta.

Comparing the above assemblage with fossils listed from the Portage and Chemung groups in central New York and adjacent parts of Pennsylvania, it is found that while some of the forms occur in beds of Portage age, they all continue well up into the Chemung[20].

Portage Group

In the sections shown in Figure 2 the term Portage has been used to designate the strata between the Genesee black shale and the base of the Chemung as delimited by Clarke and Luther in the Genesee valley section[21]. As has been pointed out under the Chemung group, this classification may require revision after the investigations of the various workers now engaged in the study of the Upper Devonian of New York and Pennsylvania have been completed.

Genesee Black Shale

The term "Genesee" has been restricted to the black shales that occupy the interval between the base of the Genundewa limestone and the top of the Tully[22].

Tully Limestone

Throughout north-central Pennsylvania the Tully limestone constitutes an excellent horizon marker for separating the Upper from the Middle Devonian. The greatest thicknesses of limestone at this horizon in the deep well sections have been encountered in Bradford and Clearfield counties, namely, 130 and 150 feet respectively. Willard has recently identified this horizon on the outcrop between Jersey Shore and Lock Haven in Lycoming and Clinton counties, where it is represented by approximately 200 feet of limestone[23].

---

19. Charles Butts: Written communication, December 10, 1929.

20. Henry S. Williams, Ralph S. Tarr, and Edward M. Kindle: Description of the Watkins Glen-Catatonk District. U.S. Geol. Survey Geol. Atlas, folio No. 169, 1909, p. 6.
Bradford Willard. Devonian Faunas in Pennsylvania. Pennsylvania Geol. Survey, Fourth Series, Bull. G 4, 1932, pp. 22-29.

21. John M. Clarke and D. Dana Luther: Geologic Map and Description of the Portage and Nunda Quadrangles. New York State Museum Bull. 118, 1908, pp. 46-47.

22. John M. Clarke and D. Dana Luther. Idem, p. 49.

23. Bradford Willard: Written communication, November 7, 1934. Portage group in Pennsylvania. Geol. Soc. America, abstracts 1934 meeting, p. 49.

In the subsurface sections the Tully limestone can be recognized as far west as Bradford and Kane. Here it has thinned to less than 5 feet. Still farther west it disappears entirely. Due to the thinning and practical disappearance of the Genesee black shale in that direction also, the Genundewa, the next limestone above the Tully, comes to occupy nearly the same position in the section. This limestone is quite thin and can only be occasionally recognized in the drill cuttings.

Middle Devonian

Hamilton Group

The Hamilton group includes the strata lying between the base of the Tully horizon and the top of the Onondaga limestone. In parts of northwestern Pennsylvania a rather prominent limestone is sometimes present in the upper part of the group at about the Tichenor horizon. In section 1 of Figure 2 a limestone 7 feet thick occurs at this horizon 371 feet above the top of the Onondaga limestone. In a deep well recently completed in Lawrence County, Pennsylvania a limestone, 20 feet thick, was encountered 250 feet above the top of the Onondaga, which, it is believed, represents the Tichenor.

Onondaga Limestone

The Onondaga limestone constitutes an excellent horizon marker throughout northwestern Pennsylvania. It consists of a very fine, crystalline, light gray to dark brownish-gray cherty limestone, ranging in thickness in 13 wells from 27 feet to 225 feet.

Lower Devonian

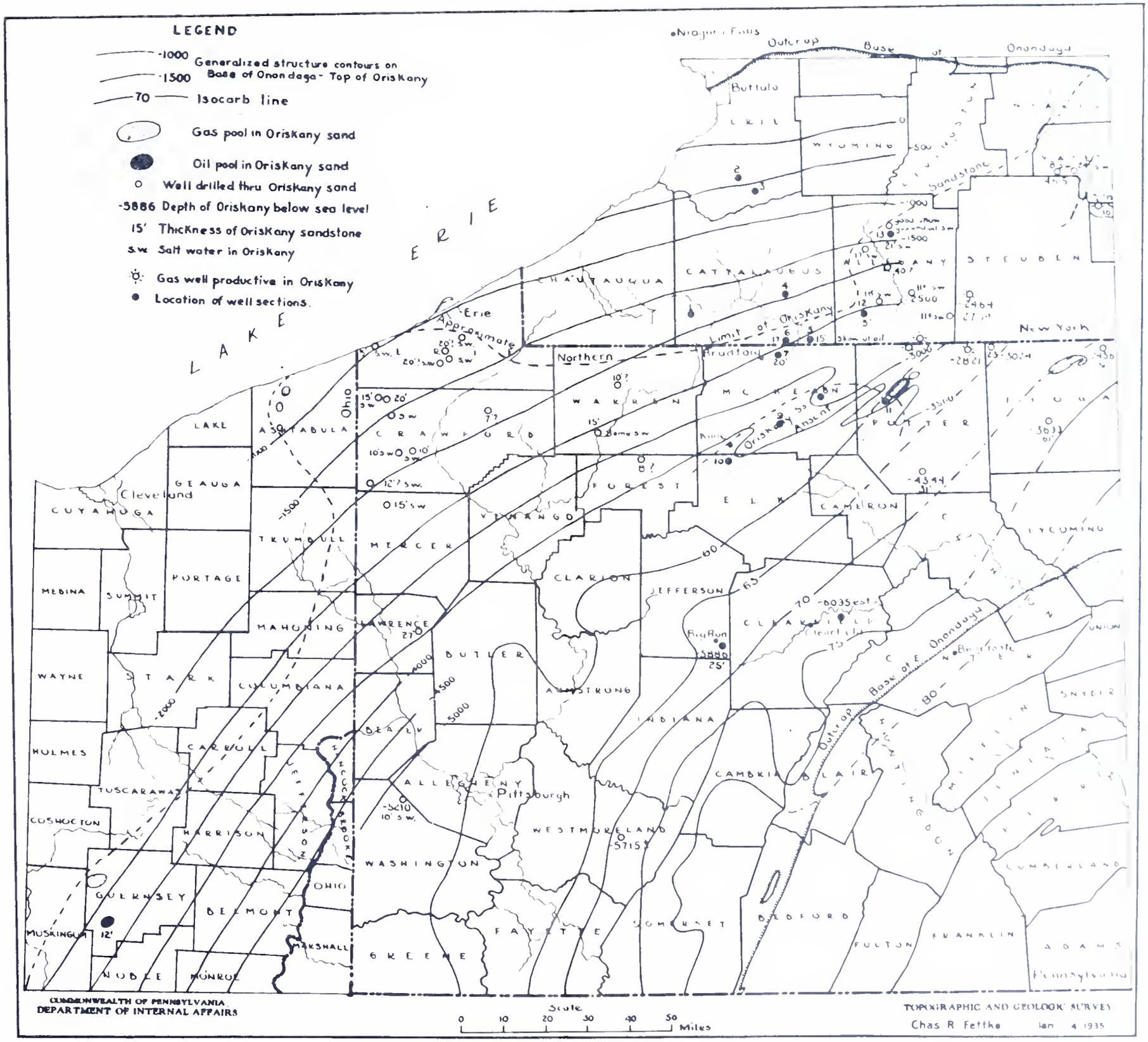
Oriskany Sandstone

Enough deep wells have already been drilled to indicate that a considerable portion of northwestern Pennsylvania is underlain by a nearly continuous bed of sandstone at the Oriskany horizon. On the north, this apparently ends along a line running in a nearly easterly direction south of the city of Erie across Erie County and probably across northern Warren County to about the McKean County line where it swings northeastward into New York State. The location of the line, as shown on Figure 1, is based upon an analysis of the data at present available. It can be considered only a rough approximation. The same is true of the line that shows the western boundary in eastern Ohio. It is also quite probable that locally small lenses of sandstone are present considerable distances beyond the limits of the more continuous body of sandstone.

Deep drilling to date in western Pennsylvania has definitely established the absence of the Oriskany sandstone in only one district within the main area. This comprises a considerable part of southern McKean and southwestern Potter counties and extends into northern Elk. The northwestern and eastern limits of this area can be roughly approximated. No information is as yet available, however, to show how far southward and southwestward it extends.

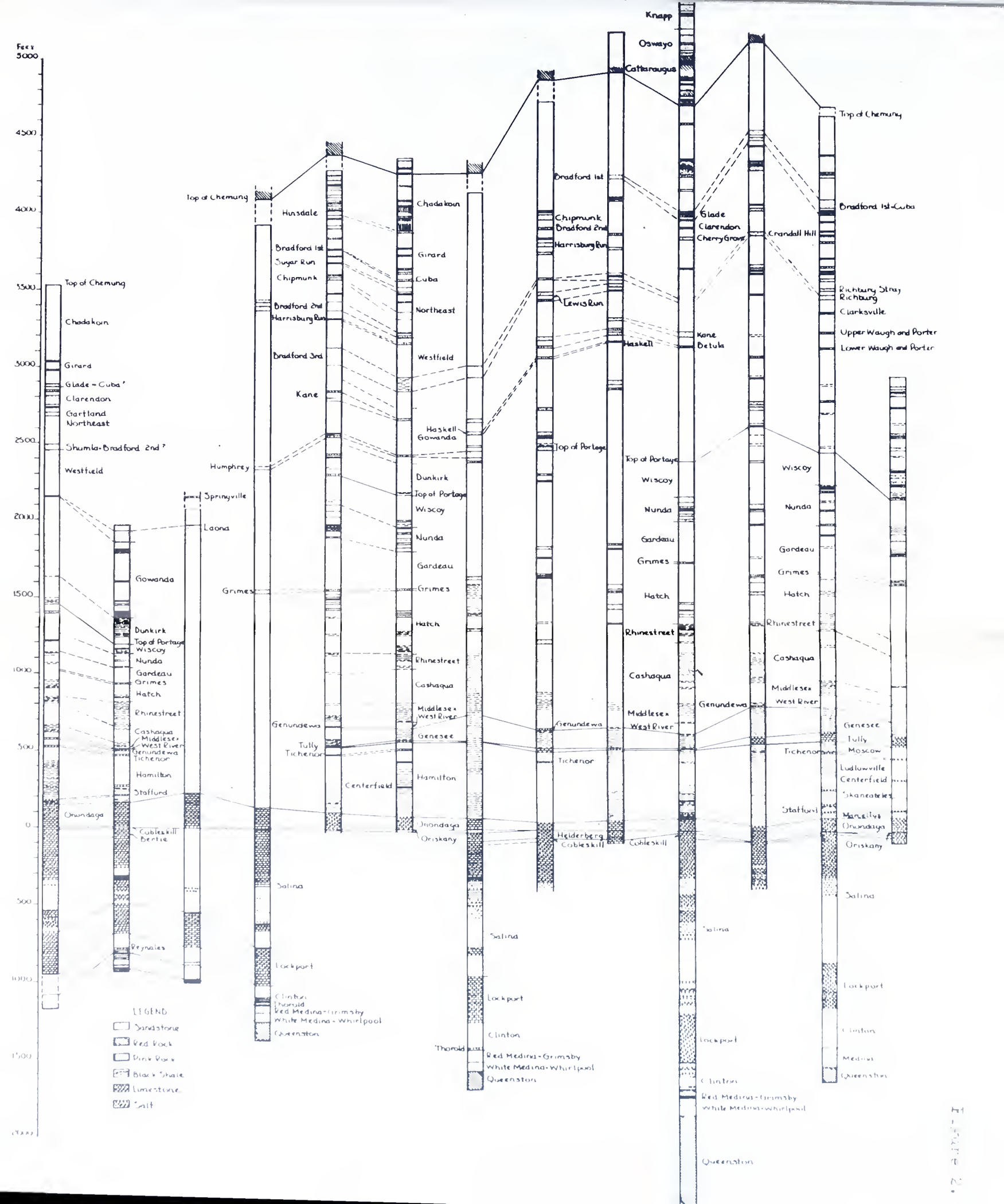
In 1920, an open flow of about half a million cubic feet of gas a day was encountered at a depth of 6822 feet at what was thought to be the Oriskany horizon in a deep well drilled by the Peoples Natural Gas Company along the Chestnut Ridge anticline at McCance in Westmoreland County. An examination of the cuttings from this horizon and the beds immediately above it, however, revealed that the gas occurred in a cherty limestone a few feet below black shales which undoubtedly represent the basal portion of the Marcellus formation of the Hamilton group. The cherty limestone in which the gas was encountered, there-

Figure 1.



COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF INTERNAL AFFAIRS

TOPOGRAPHIC AND GEOLOGIC SURVEY
Chas R Fettke Jan 4 1935


Feet
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
500
1000
1500
2000
Top of Chemung
Chadakoin
Girard
Glade = Cuba
Clarendon
Gartland
Northeast
Shumla-Bradford 2nd?
Westfield
Gowanda
Dunkirk
Top of Portage
Wiscoy
Nunda
Gardeau
Grimes
Hatch
Rhinestreet
Cashaqua
Middlesex
West River
Genundewa
Tichenor
Hamilton
Stafford
Onondaga
Cobleskill
Bertie
Reynales
Springville
Laona
Top of Chemung
Hinsdale
Bradford 1st
Sugar Run
Chipmunk
Bradford 2nd
Harrisburg Run
Bradford 3rd
Kane
Humphrey
Grimes
Genundewa
Tully
Tichenor
Centerfield
Salina
Lockport
Clinton
Thorold
Red Medina-Grimsby
White Medina-Whirlpool
Queenston
Chadakoin
Girard
Cuba
Northeast
Westfield
Haskell
Gowanda
Dunkirk
Top of Portage
Wiscoy
Nunda
Gardeau
Grimes
Hatch
Rhinestreet
Cashaqua
Middlesex
West River
Genesee
Tichenor
Hamilton
Onondaga
Oriskany
Salina
Lockport
Clinton
Thorold
Red Medina-Grimsby
White Medina-Whirlpool
Queenston
Bradford 1st
Chipmunk
Bradford 2nd
Harrisburg Run
Lewis Run
Haskell
Top of Portage
Genundewa
Tichenor
Helderberg
Cobleskill
Knapp
Oswayo
Cattaraugus
Glade
Clarendon
Cherry Grove
Kane
Betula
Top of Portage
Wiscoy
Nunda
Gardeau
Grimes
Hatch
Rhinestreet
Cashaqua
Middlesex
West River
Genundewa
Salina
Lockport
Clinton
Red Medina-Grimsby
White Medina-Whirlpool
Queenston
Top of Chemung
Bradford 1st-Cuba
Crandall Hill
Richburg Stray
Richburg
Clarksville
Upper Waugh and Porter
Lower Waugh and Porter
Wiscoy
Nunda
Gardeau
Grimes
Hatch
Rhinestreet
Cashaqua
Middlesex
West River
Genundewa
Tichenor
Ludlowville
Centerfield
Skaneateles
Stafford
Marcellus
Onondaga
Oriskany
Salina
Lockport
Clinton
Medina
Queenston
LEGEND
Sandstone
Red Rock
Pink Rock
Black Shale
Limestone
Salt

fore, either represents the Onondaga limestone or else this formation is absent entirely and the Oriskany is represented at this locality by a cherty limestone instead of a true sandstone. When an attempt was made several years later to deepen the well, salt water was encountered in the limestone a short distance below the gas-bearing horizon. Another well, about 500 feet from the first, drilled to a total depth of 7756 feet, encountered only a show of gas and no water at this horizon. Unfortunately, the drillers neglected to save samples of the cuttings from the interval immediately below the cherty limestone and no definite information is available, therefore, as to whether any true Oriskany sandstone is present. The J. S. Lightcap well of the T. W. Phillips Oil and Gas Company, northwest of Marion Center, Indiana County, drilled to a total depth of 7006 feet in 1920, probably did not reach the Oriskany horizon.

Helderberg Group

The Helderberg limestone probably is present in parts of northwestern Pennsylvania but is thin. Twenty feet of strata have been assigned tentatively to this horizon in the deep well south of Kane.

SILURIAN SYSTEM

Cobleskill Limestone

In northwestern Pennsylvania a magnesian limestone usually occurs at what has been taken as the upper limit of the Silurian system. It is thought that this represents the Cobleskill limestone of western New York. Along the outcrop of the Silurian rocks to the north, this limestone has a thickness of only 5 feet and constitutes the highest member of the system[24].

Salina Group

The Salina group as developed in northwestern Pennsylvania consists of a series of interbedded, dense, argillaceous, magnesian limestones ranging in color from light gray to dark grayish-brown, and gray shales, for the most part either calcareous or dolomitic. Beds of anhydrite and salt are also present.

Lockport Dolomite

The Lockport dolomite, underneath the Salina group, constitutes a readily recognizable horizon throughout northwestern Pennsylvania. It consists of a very fine, crystalline, brownish-gray to very dark grayish-brown dolomite. F. M. Swartz has suggested that the McKenzie shale and limestone of central Pennsylvania is the equivalent, at least in part, of the Lockport dolomite[25].

---

[24] E. M. Kindle and Frank B. Taylor: Description of the Niagara Quadrangle. U. S. Geol. Survey Geol. Atlas, folio No. 190, 1913, p. 8.

[25] F. M. Swartz: Correlation of the McKenzie Shale. Geol. Soc. America, Bull., vol. 41, 1930, pp. 117-118.

Silurian Section near Mount Union, Central Pennsylvania. Geol. Soc. America, Bull., vol. 45, 1934, p. 126.

Clinton Group

The term Clinton group has been applied to the strata occupying the interval between the base of the Lockport dolomite and the top of the Medina sandstone. The group, therefore, includes the Rochester shale at the top and the Thorold sandstone at the base, as well as the Clinton formation proper.

Medina Group

The Medina group has been restricted to those strata which lie between the base of the Thorold sandstone and the top of the Queenston shale. Throughout northwestern Pennsylvania the group has very much the same characteristics as in the Niagara section.

On the basis of color, drillers usually divide it in two parts in their logs, the upper portion or Grimsby being designated as the Red Medina and the lower, or Whirlpool, the White Medina. In the Niagara gorge section, the red color is confined to the upper 48 feet of sandstones and sandy shales, the lower 46 feet being gray or white[26].

At Derrick City (Section 7, Figure 2) the upper 82 feet are red and the lower 58 feet gray or white. In the Kane deep well (Section 10, Figure 2) 110 miles south of the outcrop, the Red Medina has a thickness of 70 feet and the White Medina, 96 feet. As in the Niagara gorge section, the latter is underlain by the Queenston red shale, of which 688 feet had been penetrated when drilling was stopped.

In the vicinity of Bellefonte, 70 miles southeast of tho Kane deep well, the Red Medina has almost disappeared along the outcrop. F. M. Swartz has recently proposed the name "Castanea sandstone" for a thin series of red and green sandy beds occasionally found at the top of the Tuscarora sandstone in central Pennsylvania which probably represent the attenuated edge of the Red Medina[27]. The White Medina, on the other hand, thickens to nearly 600 feet, forming the well-known Tuscarora sandstone, and the underlying Queenston red shales pass into the red shales and sandstones that comprise the Juniata formation.

Attention should here be called to the fact that J. P. Lesley, Director of the Second Pennsylvania Geological Survey, called the Tuscarora sandstone of central Pennsylvania the Medina white sandstone and the Juniata formation, the Medina red sandstone[28]. Lesley's Medina red sandstone is the equivalent of the Queenston red shale and underlies the so-called White Medina of western New York and northwestern Pennsylvania, whereas, the so-called Red Medina of the drillers in western New York overlies the White Medina and is probably represented in central Pennsylvania by Swartz's Castanea sandstone.

---

[26] E. M. Kindle and Frank B. Taylor: Op. cit., p. 6.

[27] F. M. Swartz: Silurian Section near Mount Union, Central Pennsylvania. Geol. Soc. America, Bull., vol. 45, 1934, p. 109.

[28] J. P. Lesley: A Summary Description of the Geology of Pennsylvania. Pennsylvania Second Geol. Survey, Final Report, vol. 1, 1892, p. 625.

ORDOVICIAN SYSTEM

Queenston Shale

The Queenston red shale is the oldest formation that has thus far been reached by the drill in northwestern Pennsylvania with one exception. The Erie deep well is reported to have penetrated the Trenton limestone of the Middle Ordovician.

Whether the Silurian-Ordovician boundary should be drawn at the top of the Queenston red shale is still a debated question amongst stratigraphers. There are some who think that it occurs below the Queenston. The New York and Pennsylvania Geological surveys include the Juniata (Queenston) shale in the Silurian system[29].

THICKENING OF BEDS SOUTHEASTWARD

Throughout much of the Paleozoic era, the Appalachian region consisted of a slowly subsiding geosyncline or trough, occupied by a shallow arm of the sea, into which sediments were washed from a landmass lying to the east and southeast. Deposition and subsidence were greatest along the eastern margins of this trough. Starting in northwestern Pennsylvania, therefore, most of the formations thicken as one goes southeastward. This is illustrated by the series of sections shown in Figures 2 and 3.

Between Sections 1 and 10, the Upper Devonian beds, exclusive of the Conewango group, increase from 2960 to 4131 feet, an average of 33 feet per mile; between Sections 4 and 8, from 3510 to 4360 feet, also an average of 33 feet per mile; and between Sections 12 and 11, from 4082 to 4559 feet, an average of 22 feet per mile.

The interval between the base of the Onondaga limestone and the top of the Medina between Sections 1 and 10 increases from 1090 to 1676 feet, an average of 16 feet per mile; between the Niagara section and Section 2, from 690 to 812 feet, an average of 3 feet per mile; between Sections 2 and 4, from 812 to 1148 feet, an average of 11 feet per mile; between Sections 4 and 7, from 1148 to 1425 feet, an average of 18 feet per mile; and between Sections 12 and the exposed section in the vicinity of Bellefonte, from 1391 to about 2600 feet, an average of about 14 feet per mile.

Location of Sections shown in Figure 2.

1. Hotchkiss No. 2 well of Arkansas Fuel Oil Company, 1½ miles south of Randolph, in Town of Randolph, Cattaraugus County, New York.

---

29. Winifred Goldring; Handbook of Paleontology for Beginners and Amateurs, Part 2: The Formations. New York State Museum Handbook 10, 1931, p. 317.
George H. Ashley: A Syllabus of Pennsylvania Geology and Mineral Resources, Topo. and Geol. Survey of Pennsylvania, Bull. G 1, 1931, p. 62.

2. Iroquois Gas Corporation's No. 796 well, 2 miles east of New Oregon, in Town of Conoord, Erie County, New York.

3. Iroquois Gas Corporation's No. 844 well, 1½ miles north of Springville, in Town of Concord, Erie County, New York.

4. L. B. Autman (Hale) No. 1 well of Hanley & Bird and Belmont Quadrangle Drilling Corporation, 2 miles south of Humphrey in Town of Humphrey, Cattaraugus County, New York.

5. J. Brooke Reed's Quinlan No. 1 well, near head of Indian Creek, 1 mile north of State line in Town of Olean, Cattaraugus County, New York.

6. J. Brooke Reed's Ryder-Scott No. 1 well, near the head of Chipmunk Creek, 1.2 miles north of State line in Town of Allegany, Cattaraugus County, New York.

7. Bradford Deep Well Company's well at Derrick City, Foster Township, McKean County, Pennsylvania.

8. North Penn Gas Company's Zerbe well, 3½ miles west of Port Allegany, Liberty Township, McKean County, Pennsylvania.

9. Benjamin Haywood No. 1 well of Atlantic Seaboard Natural Gas Company, Inc., 0.7 mile west of Marvindale, Hamlin Township, McKean County, Pennsylvania.

10. United Natural Gas Company's No. 3737 well on Warrant 3788, 4 miles south of Kane, Highland Township, Elk County, Pennsylvania.

11. A. Matteson No. 1 well of Potter Development Company, 5 miles northeast of Roulette, Hebron Township, Potter County, Pennsylvania.

12. Belmont Quadrangle Drilling Corporation's Gilbert well, 2 miles north of Richburg, in Town of Wirt, Allegany County, New York.

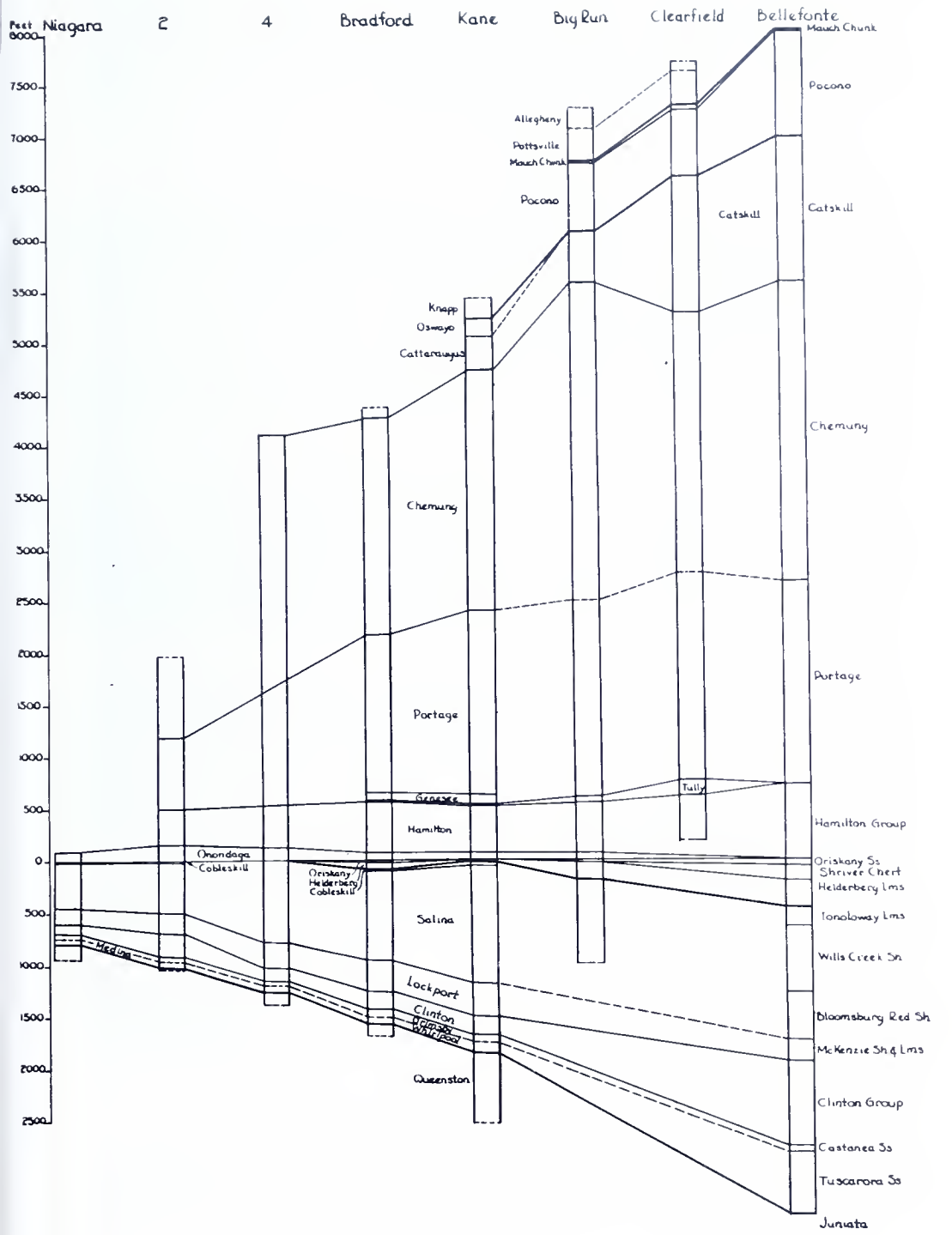
13. Arthur Sheldon No. 1 well of S. J. Brendel and Associates, 1 mile north of West Allen, in Town of Allen, Allegany County, New York.

GAS AND OIL POSSIBILITIES OF THE DEEPER SANDS

Oriskany Sandstone

Early in the present century a small gas pool was opened up in the vicinity of Austinburg in northeastern Ohio in a sandstone occurring at the Oriskany horizon. Ten years ago, gas in commercial quantities was encountered in the Oriskany sandstone northwest of Cambridge in Guernsey County, Ohio, and a few years later, a small oil pool was opened in the same formation southwest of Cambridge. It has been the discovery of relatively large volumes of gas in the Oriskany sandstone in the Wayne-Tyrone pool in Schuyler County, New York in March, 1930; in the Tioga pool in Tioga County, Pennsylvania, in September, 1930; and the Hebron pool in Potter County, Pennsylvania, in November, 1931, however, that has focused attention upon this formation as a potential source of gas and possibly oil throughout the Appalachian plateau province.

Figure 3


Feet
Niagara
2
4
Bradford
Kane
Big Run
Clearfield
Bellefonte
8000
7500
7000
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
500
1000
1500
2000
2500
Allegheny
Pottsville
Mauch Chunk
Pocono
Knapp
Oswayo
Catteraugus
Chemung
Portage
Genesee
Hamilton
Onondaga
Cobleskill
Oriskany
Helderberg
Cobleskill
Salina
Medina
Lockport
Clinton
Queenston
Catskill
Tully
Mauch Chunk
Pocono
Catskill
Chemung
Portage
Hamilton Group
Oriskany Ss
Shriver Chert
Helderberg Lms
Tonoloway Lms
Wills Creek Sh
Bloomsburg Red Sh
McKenzie Sh & Lms
Clinton Group
Castanea Ss
Tuscarora Ss
Juniata

Outside the above pools, gas has been encountered in a well along the Harrison anticline in northeastern Potter County, Pennsylvania and in several wells along the Smethport anticline in northern Potter County and in southeastern Allegany and southwestern Steuben counties, New York. The extent of the productive areas in these localities has not as yet been determined. Good shows of oil have been found in Allen Township in northern Allegany County and in the Knapps Creek dome area of the Bradford field in the southeastern part of Cattaraugus County, New York, but no commercial production has been developed in these areas to date. The recent discovery of oil in apparently commercial quantities at this horizon in Kanawha County, West Virginia has greatly extended the territory in which the Oriskany may be considered a potential source of gas and oil.

Structure

Structurally, the Appalachian plateau province consists of a broad asymmetrical synclinorium or basin, whose long axis trends in a northeasterly-southwesterly direction with the steeper limb on the southeast side. The monoclinal structure of the Oriskany sandstone in northwestern Pennsylvania with an approximate northeasterly and southwesterly strike and an average dip of about 42 feet to the mile in a southeasterly direction represents part of the northwestern limb of this synclinorium. The southeastern limb is modified by a series of rather prominent anticlinal and synclinal folds with axes trending approximately parallel to the long axis of the synclinorium. The folds become less prominent in the central part of the basin and are hardly perceptible on the northwestern limb.

The structure contours on the Oriskany horizon on the map (Figure 1) have necessarily had to be very much generalized on account of the relatively small number of wells that have thus far been drilled to this horizon in the area. It is believed, however, that they are sufficiently accurate to be useful as a guide in estimating approximate depths to the Oriskany. The contours show the depth of the top of the Oriskany or its equivalent horizon below sea level. By adding the elevation of the surface above sea level, the depth to the Oriskany at any particular locality in the area contoured can be roughly estimated.

In north central Pennsylvania in Potter and Tioga counties, gas in the Oriskany has been encountered only on well-defined domes along pronounced anticlinal structures. The surface geology of northwestern Pennsylvania gives no indications of the existence of such well-defined structures in this part of the State. Cathcart's recent work on the surface geology of Crawford, Erie, and Warren counties, however, does show that structural noses (plunging anticlines), terraces (flats), and even gentle domes can be recognized in the outcropping beds[30]. It cannot be assumed, however, that these surface structures are vertically superimposed upon similar structures at the Oriskany horizon. Convergence between the key beds at the surface and the Oriskany may considerably shift the axes and change the outlines of such structures at the deeper horizon.

Gas and oil pools are sometimes associated with minor structural features of the type referred to above that interrupt, to a slight degree at least, the uniform dip of a monoclinal structure. Areas in which structures of this type exist would afford the best chances of obtaining production in the Oriskany in northwestern Pennsylvania.

---

30. S. H. Cathcart: Geologic Structure of Northwest Pennsylvania Has Deep Sand Possibilities of Gas and Oil. Oil and Gas Journal, December 20, 1934, pp. 58-59.

Cementation and Metamorphism

Only drill cuttings of the Oriskany sandstone have been available for examination from northwestern Pennsylvania. In most cases, some calcium carbonate is present as a bond and some secondary silica has invariably been deposited on the original quartz grains. Both the calcium carbonate and the secondary silica have reduced the porosity of the rock and hence its capacity to hold fluids, either gas, oil, or water. In some instances the cementation has apparently been so thorough that no fluids are encountered when the horizon is penetrated by the drill. However, the fact that at a number of widely separated localities in Erie, Crawford, and Mercer counties considerable quantities of salt water have been reported from this horizon indicates that, in these areas at least, the Oriskany sandstone must still retain a considerable percentage of its original pore space.

The degree of cementation is closely related to the amount of metamorphism that the rocks have undergone. In the Appalachian region, the thrusts responsible for the folding and uplift of the strata at the close of the Paleozoic era were directed from the southeast. The degree of metamorphism that the beds have undergone, therefore, increases progressively in that direction.

Coals are particularly susceptible to metamorphic alteration. The percentage of fixed carbon computed on a pure coal basis in the case of bituminous and higher rank coals constitutes an excellent criterion for judging the degree of metamorphism that the associated strata have undergone, the fixed carbon increasing with the intensity of the metamorphism. On Figure 1, the progressive increase of the metamorphism in the coals toward the southeast is shown by the isocarb lines.

It will be noted that the Tioga gas pool, the most easterly of the Oriskany sand pools in Pennsylvania, is crossed by the 70 isocarb line. Although there has been considerable drilling on equally well defined structures to the east and southeast in both Tioga and Bradford counties, no production has resulted. In every instance, although the Oriskany sandstone was present, it was found to be so tightly cemented that it was no longer capable of acting as a reservoir rock for the retention of fluids.

In Pennsylvania all the major gas pools productive in the Upper Devonian and higher strata lie northwest of the 65 isocarb line. Only a few minor pools have been encountered between the 65 and 70 lines and the amount of gas that has been obtained from these strata southeast of the 70 line is almost negligible. Most of Pennsylvania's oil production has come from that area west and northwest of the 60 isocarb line. A few oil pools occur between the 60 and 65 lines and only very minor amounts of oil have been obtained from the area southeast of the latter line.

The intensity of metamorphism also increases with depth. The deeper sands, such as the Oriskany, can, therefore, be expected to have undergone a greater degree of metamorphism than the Upper Devonian and higher sands. The possibilities of obtaining commercial quantities of gas from the Oriskany in that part of Pennsylvania lying southeast of the 70 isocarb line can, therefore, be considered to be only slight.

Gas and Oil Possibilities of the Oriskany

The probable existence of a nearly continuous body of sandstone at the Oriskany horizon in northwestern Pennsylvania which, in parts of the area at least, retains a fair percentage of porosity, as witnessed by the amounts of salt water encountered in it, is the factor most favorable to the possible occurrence of commercial quantities of gas and oil. On the other hand, the

sandstone is probably comparatively thin over the entire area. Thicknesses in the wells drilled through it thus far range from 5 to 27 feet, with the average somewhat less than 15 feet. Large total yields per acre of productive area, therefore, cannot be expected even if future prospecting should lead to the development of commercial production.

Most important of all probably is whether or not sufficiently prominent structures were present that acted as traps and brought about a segregation from the associated salt water of gas and oil migrating up the monoclinal slope when conditions were favorable for the accumulation of gas and oil deposits. Careful geological mapping supplemented perhaps by geophysical surveys will be necessary to discover any such structures, if they exist. Areas near the margins of the main sandstone body where this plays out up the dip and is sealed off by joining of the overlying and underlying rocks can also be looked upon as favorable territory.

In spite of the fact that all the tests to date in the area under discussion have proved failures, the possibilities of eventually obtaining some commercial production of gas and oil in this part of Pennsylvania in the Oriskany can by no means be considered to be negligible. The number of tests to date is still quite small, considering the size of the area involved. Also, very few of the wells drilled in the past were located on the basis of any preliminary geological investigations.

Salina Group

In 1924 an open flow of about 240,000 cubic feet of gas per day was encountered in the Salina between the depths of 7428 and 7440 feet in the Booth and Flynn No. 2 well of the Peoples Natural Gas Company near McCance, Westmoreland County. The gas contained some hydrogen sulphide and had to be treated chemically before it was turned into the line. The horizon at which the gas occurred is about 600 feet below the top of the Onondaga.

Shows of gas and some salt water have been reported in the Salina in a number of other deep wells in western Pennsylvania but, with the above exception, no commercial production has resulted. The Salina group has not proved productive in the adjacent States of New York and Ohio and it is not likely that any significant amounts of gas or oil will be obtained from it in Pennsylvania.

Lockport Dolomite

Gas and some oil were discovered in 1911 in a granular, porous dolomite in the Niagara limestone at South Newburg in the southern part of Cleveland, Ohio. This horizon has since been called the Newburg "sand". At the type locality it occurs about 250 feet below the top of the Niagara limestone, which corresponds closely in geologic age to the Lockport dolomite of western New York and northwestern Pennsylvania[31]. The Newburg sand has proved productive at several localities in Ohio.

In the R. C. Jamison well in South Shenango Township, Crawford County, Pennsylvania, a little gas and a good show of oil were encountered at a depth

---

31. Frank R. Van Horn: Economic Geology of the Cleveland District, Ohio. U. S. Geol. Survey, Bull. 813, 1931, pp. 117-120.

of 4080 and 4096 and considerable salt water between 4115 and 4121 feet in the Lockport dolomite. The top of the dolomite occurs at about 3925 feet and it is 285 feet thick. This horizon probably corresponds rather closely to the Newburg of Ohio. Salt water has also been reported in the Lockport in northwestern Pennsylvania in several other deep tests. The horizon can be considered to offer some possibilities as a potential source of gas and oil in this area.

Medina Group

The sandstones of the Medina group have been the great source of gas in western New York and central Ohio. In central Ohio some oil has also been obtained from them. The Medina has, therefore, been the objective of a considerable number of the deep tests undertaken in western Pennsylvania and wells have reached it in Erie, Crawford, Warren, McKean and Elk counties. While no gas pools have been discovered in it thus far in northwestern Pennsylvania, a fair show of gas has been encountered at several widely separated localities. In the Miles farm well of Cowgen and Eckert in Springfield Township, Erie County, an open flow of about 600,000 cubic feet of gas per day was reported in 1932. A little water occurred below the gas. In the Ulf well of the Fidelity Petroleum Corporation at Tidioute in Warren County, approximately 15,000 cubic feet of gas per day was encountered in the Red Medina and 100,000 cubic feet in the White Medina, and in the James Naylor Lands well of the United Natural Gas Company in Vernon Township, Crawford County, approximately 30,000 cubic feet in the White Medina.

The Medina sandstones undoubtedly underlie all of western Pennsylvania. Inasmuch as the interval between the base of the Onondaga or the top of the Oriskany and the top of the Medina increases in a southeasterly direction, the regional dip of this formation toward the southeast is steeper than that of the Oriskany sandstone. Between the Miles and the James Naylor Lands wells this interval increases from 937 to 1187 feet in a distance of about 27 miles or an average of about 9 feet per mile and between the Randall well of the Allegany Gas Company, south of Chautauqua, New York and the Ulf well from 825 feet to 1266 feet in a distance of 32 miles, or an average of 14 feet per mile.

It is not thought likely that oil in paying quantities is present in the Medina in northwestern Pennsylvania. The horizon can, however, be regarded as a possible source of gas and is worthy of further testing. Inasmuch as it occurs at a considerably lower stratigraphic horizon than the Oriskany, it has no doubt undergone a greater degree of cementation and metamorphism. Two fragments obtained from the White Medina sandstone in the Kane deep well of the United Natural Gas Company possessed total porosities of only 3.3 and 3.6 per cent by volume respectively. Whether or not it retains sufficient porosity anywhere in western Pennsylvania to constitute a reservoir rock for commercial quantities of gas can only be determined by the drill. The northwestern counties would seem to offer the most favorable territory for testing.

Just how important a role the structure has played in the accumulation of gas in the Medina of western New York and central Ohio has not been definitely established. In many instances there is good evidence that the gas has been trapped in minor structural irregularities, such as gentle structural noses or bulges and terraces. In some cases, however, conditions of sedimentation resulting in local variations in porosity and permeability appear to have been the major factors in determining the location of the pools. It must also be kept in mind that the gas deposits of the Medina may have accumulated a considerable time before the earth movements took place that brought about the present structural features. Part at least of the cementation may also have occurred prior to this time. It is difficult to predict, therefore, to what extent the minor structural features, such as can be mapped on the outcropping beds in northwestern Pennsylvania, will be useful in locating favorable areas for testing the Medina. It is thought, however, that, on the whole, wells located on the basis of careful structural studies will have a better chance of success than those located at random. Convergence between the key beds mapped and the Medina should not be lost sight of in projecting structures on the latter.